

Incidence of Ankle Sprains Among Active-Duty Members of the United States Armed Services From 1998 Through 2006

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Context: Ankle sprains have been reported as one of the most common injuries sustained by members of the US Armed Services. However, little is known about the incidence rate and injury patterns associated with ankle sprains in this population.

Objective: To examine the incidence of ankle sprains among active-duty members of the US Armed Services from 1998 through 2006. A secondary objective was to describe the sex, age, and service-specific injury patterns in this young, physically active population.

Design: Cohort study.

Patients or Other Participants: All active-duty service members from the day they enter military service until the day they leave military service and US Army Reserve and National Guard service members during periods of active duty and mobilization.

Main Outcome Measure(s): Injury data were extracted from the Defense Medical Epidemiological Database from 1998 through 2006. All data for ankle sprains, coded according to the *International Classification of Diseases* (9th revision), were included. Cases were limited to those injuries reported as first

occurrences. Incidence rates (IRs) were calculated per 1000 person-years by sex, age, and service. Incidence rate ratios (IRRs) and 95% confidence intervals (95% CIs) were used to assess the strength of association between the incidence of ankle sprain and the independent variables of sex, age, and service.

Results: From 1998 through 2006, 423 581 service members sustained ankle sprains and 12 118 863 person-years at risk to injury were documented in this population. The incidence rate was 34.95 (95% CI = 34.85, 35.06) per 1000 person-years at risk. Females were 21% more likely (IRR = 1.21, 95% CI = 1.21, 1.23) to sustain an ankle sprain than males. Sex-specific IRR varied by age and service. Differences in the rate of ankle sprains were also noted by age and service.

Conclusions: The incidence of ankle sprains among US service members was 5 times greater than that previously reported in civilian population studies. Sex, age, and branch of military service are important factors related to the incidence of ankle sprains in this population.

Key Words: injury epidemiology, injury surveillance, military populations

Key Points

- Our study is one of the first large-scale, population-based epidemiologic investigations to examine the incidence of ankle sprain injuries and the first to examine ambulatory injury data within a military population.
- In this population, ankle sprains occurred at a rate more than 5 times greater than that seen in civilian populations.
- Overall, females were 21% more likely than males to sustain ankle sprains. The greatest discrepancy (nearly 60%) was noted among male and female Marine Corps members.
- Ankle sprain incidence rates were highest in service members who were less than 20 years old and declined with age.

Service members in the 4 branches of the US military represent a large and physically active population that has been shown¹ to sustain a number of soft tissue and athletic injuries. In addition to athletic injuries, the physical fitness and training-related requirements of military service increase soldiers' risk for musculoskeletal injury in general and injury to the lower extremity and ankle specifically.¹⁻⁴ Ankle sprains are one of the most common injuries sustained by members of the US Armed Services and are among the leading causes of sport-related and physical training-related hospitalizations in the military.¹ In general, ankle sprains are often undertreated and result in chronic pain, muscular weakness, and chronic instability.⁵ Among service

members, ankle sprains frequently result in significant time loss and persistent disability and are second only to low back pain in relation to the overall percentage of the rehabilitation workload.^{3,6} Despite the effect of ankle sprains on the physical and operational readiness of our military, the incidence of ankle sprains among US service members has not been examined thoroughly.

Since 1997, the Defense Medical Surveillance System (DMSS) has been the central repository for data related to all health care encounters between providers and beneficiaries in all 4 branches of US military service.⁷ More than 300 million data records (from more than 20 different sources) are stored within the DMSS database.⁸ The DMSS captures injury and illness data for all

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hospitalizations and ambulatory visits service members make to Department of Defense network health care providers worldwide. The structure, capabilities, and utility of DMSS for public health surveillance and epidemiologic research have been described in the literature.^{7,8} The DMSS database contains both current and historical data on diseases and medical events (eg, hospitalizations, ambulatory visits, reportable diseases, human immunodeficiency virus tests, immunizations, and health risk appraisals) and longitudinal demographic data relevant to personnel characteristics and deployment experiences for all active-duty and reserve component service members. Data in DMSS originate from many different sources within the Department of Defense. The DMSS provides access to 4 types of data relevant to active-duty service members: demographic data, inpatient hospitalization data, ambulatory data, and reportable events data.⁸ The Armed Forces Health Surveillance Center operates DMSS and is a component of the US Army Center for Health Promotion and Preventive Medicine.

Because of their unique skill set, certified athletic trainers have begun to see the emergence of opportunities to work with active-duty military populations. It will be important for certified athletic trainers and athletic training educators to have a better understanding of injury patterns and health care needs within this physically active population as these emerging injury prevention opportunities begin to materialize. The purpose of our study was to examine the incidence of ankle sprains among active-duty members of the US Armed Services from 1998 through 2006 using data extracted from DMSS. A secondary objective was to describe the sex-specific, age-specific, and service-specific injury patterns for ankle sprains among active-duty service members.

METHODS

Design and Setting

A retrospective cohort study was conducted to examine injury data extracted from DMSS related to the primary occurrence of ankle sprain injuries among US service members on active duty from 1998 through 2006. The population includes all service members from the day they enter military service until the day they leave military service and US Army Reserve and National Guard service members during periods of service mobilization and active duty. The entire population has free and open access to medical care within the Military Healthcare System, and these encounters are documented with standardized records.⁷ Furthermore, injury records for US service members treated in outsourced network and nonmilitary facilities are also documented in DMSS, as all care is covered under TRICARE, the Military Healthcare System's health care program. As a result, nearly all injury data related to ankle sprains for the entire population on active duty in the US Armed Forces during the study period were captured in DMSS. Under the provision for the "Secondary Use of Existing Data for Epidemiological Research," study exemption for this investigation was granted by the Institutional Review Board at Keller Army Hospital (West Point, NY), with secondary review by the US Army

Clinical Investigation Regulatory Office (Fort Sam Houston, TX).

Defense Medical Surveillance System

The DMSS is an executive information system for medical surveillance and decision support through the Military Healthcare System.⁸ The DMSS is a relational database of current and historical data categorized by medical events, personnel characteristics, and military experience for all US service members over the course of their entire military careers.⁸ The Armed Forces Health Surveillance Center provides a Web-based application, the Defense Medical Epidemiological Database (DMED), which can be used by researchers to query the epidemiologic data contained within DMSS. This interface provides authorized users worldwide access to real-time, user-defined queries of a subset of de-identified data contained within DMSS.⁸ Injury counts by *International Classification of Diseases* (9th revision; ICD-9)⁹ codes, population statistics by strata (person-years at risk to injury), and incidence rates can be queried by several demographic variables (eg, sex, age, rank, service, marital status) using the DMED application.

Data Acquisition and Outcome Assessment

For the purposes of this study, injury data were extracted from DMSS using the DMED interface. All data in DMSS are coded according to the ICD-9 coding definitions.⁹ Specifically, we combined data for ambulatory visits with ICD-9 codes 845.00 (unspecified ankle sprain), 845.01 (deltoid ligament sprain), 845.02 (calcaneofibular ligament sprain), 845.03 (distal tibiofibular ligament sprain), and 845.09 (other ankle sprain). We operationally defined an *ankle sprain* as any injury resulting in an ambulatory visit that was classified using one of the above ICD-9 codes. All ICD-9 codes for ankle sprain were included in this investigation in order to document all ankle sprain injuries within this population. For every ambulatory visit service members make, up to 4 diagnoses can be recorded, with the first diagnosis indicating the primary reason for the visit. According to the Armed Forces Health Surveillance Center,⁸ additional diagnoses are generally less reliable or are related to multiple trauma events, such as automobile accidents. As a result, data were only included if the codes were listed as the primary (first) diagnosis documented in DMSS. In addition to primary diagnosis, only cases reported as "first occurrences" were included in the data. Events were limited to "first occurrence" to exclude repeat coding of the same initial injury for all services during the study period.⁸

The main outcome of interest was the rate of ankle sprain injuries per 1000 person-years at risk to injury during the study period. Incidence rates (IRs) are calculated by dividing the total number of injuries observed in a population by a measure of person-time at risk to injury.¹⁰ Person-time at risk can be defined in a number of ways. Although athlete-exposure to injury has commonly been used as a measure of person-time at risk in sports injury research, person-years at risk is a more widely used measure of exposure in population-based epidemiologic studies. Knowles et al¹⁰ recommended collecting data for

person-time at risk to injury as precisely as possible, and person-years at risk to injury is the most precise measure of exposure available for injury data in DMSS. Accurate population denominator data (person-years at risk to injury) are accessible through the DMSS and are validated against Department of Defense personnel data obtained from the Defense Manpower Data Center.⁸ The Defense Manpower Data Center provides accurate information that is used to calculate person-time at risk based on the date of entry into military service and the date of separation from military service for all active-duty military personnel across each stratum. For US Army Reserve and National Guard components of the US Armed Services, person-time at risk is based on dates of mobilization to and demobilization from active-duty military service. All incidence rates are reported per 1000 person-years at risk to injury.

Statistical Analysis

Using the injury and personnel data extracted from DMED, IRs with 95% confidence intervals (CIs) were calculated per 1000 person-years at risk to injury for the entire population and by sex, age, and service. The age categories used were less than 20, 20 to 24, 25 to 29, 30 to 34, 35 to 39, and equal to or greater than 40 years. The service categories were US Army, US Marine Corps, US Navy, and US Air Force. Incidence rate ratios (IRRs) between male and female service members and 95% CIs were calculated by age and service using females as the referent group. Finally, within each age category, IRRs and 95% CIs were calculated between services within the sexes.

We used IRR point estimates and precision of the estimates, measured by each ratio's 95% CI, as a measure of the strength of association between the incidence of ankle sprain and the independent variables of sex, age, and service. The IRR is a standard epidemiologic measure for assessing the increase in the rate of sustaining an injury in one group relative to sustaining an injury in another group for a given variable. An IRR has a meaningful interpretation as the relative risk of injury associated with each risk factor or independent variable. The IRR also provides information about the magnitude of statistically significant differences in injury risk between groups. An IRR with a CI that includes 1.0 is interpreted as representing no statistically significant association between groups. An IRR of 1.15 or 0.85 would correspond to a 15% difference in the rate of ankle sprains, and a 15% difference in the rate of ankle sprain injuries should be interpreted as clinically significant.¹¹

RESULTS

During the 9 years from 1998 through 2006, a total of 423 581 service members made ambulatory visits for ankle sprains. During the same period, 12 118 863 person-years at risk to ankle injury were documented in DMSS, with an average of 1 346 540 US service members at risk for injury each year. Overall, the IR for ankle sprains among active-duty US service members was 34.95 (95% CI = 34.85, 35.06) per 1000 person-years at risk. The proportion of ankle sprain injuries by ICD-9 code, as documented in DMSS, is presented in Figure 1: more than 92% of all

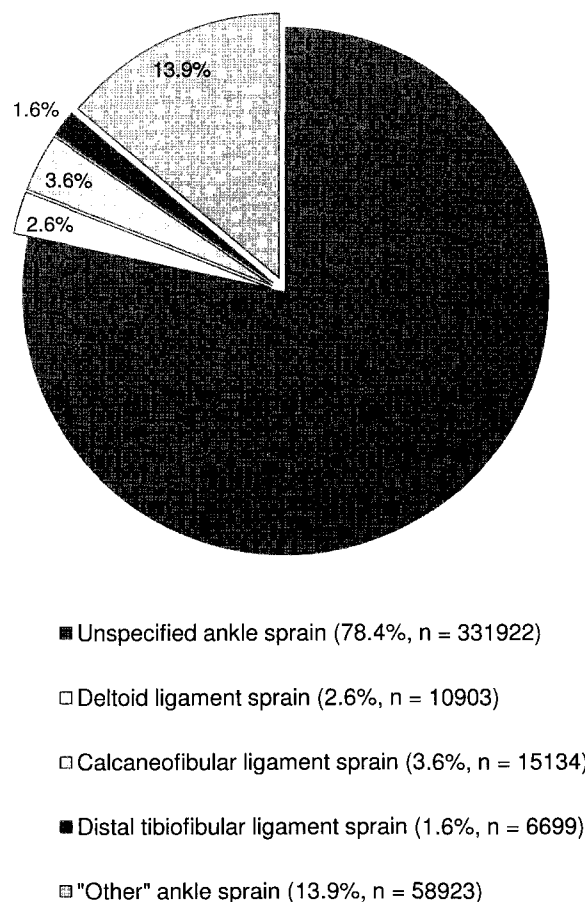


Figure 1. Proportion of ankle sprains by International Classification of Diseases (9th revision; ICD-9)^a code among US service members, 1998–2006. The total number of ankle sprains was 423 581.

injuries were coded as unspecified ankle sprain (845.00) or other ankle sprain (845.09).

Among all service members, females were 21% more likely than males to sustain an ankle sprain. For males, the IR was 33.89 (95% CI = 33.78, 34.00) injuries per 1000 person-years at risk; for females, the IR was 41.17 (95% CI = 40.88, 41.46). The greatest discrepancy between males and females was noted among service members within the Marine Corps. When all age groups were examined collectively, females were nearly 60% more likely to sustain an ankle sprain than their male counterparts. Similarly, females in the Army and Navy also experienced ankle sprain injuries more frequently than did male service members. Males and females in the Air Force were at equal risk for ankle sprain. The IRs for ankle sprains by sex and service are presented in Figure 2.

Examining the IRs by sex and age within each service revealed similar trends among active-duty service members in the Marine Corps, Army, and Navy. For both males and females, IRs were the highest in those service members who were younger than 20 years of age. The IRs declined sharply between those in the under 20-year and the 20 to 24-year age groups and continued to decline steadily with age. For ankle sprain injuries, incidence rates were higher for females than for males within each age group in these 3 branches of service (Table 1). The only exception was noted in the Navy 25 to 29-year age group, with males and females experiencing equal rates of injury. The greatest

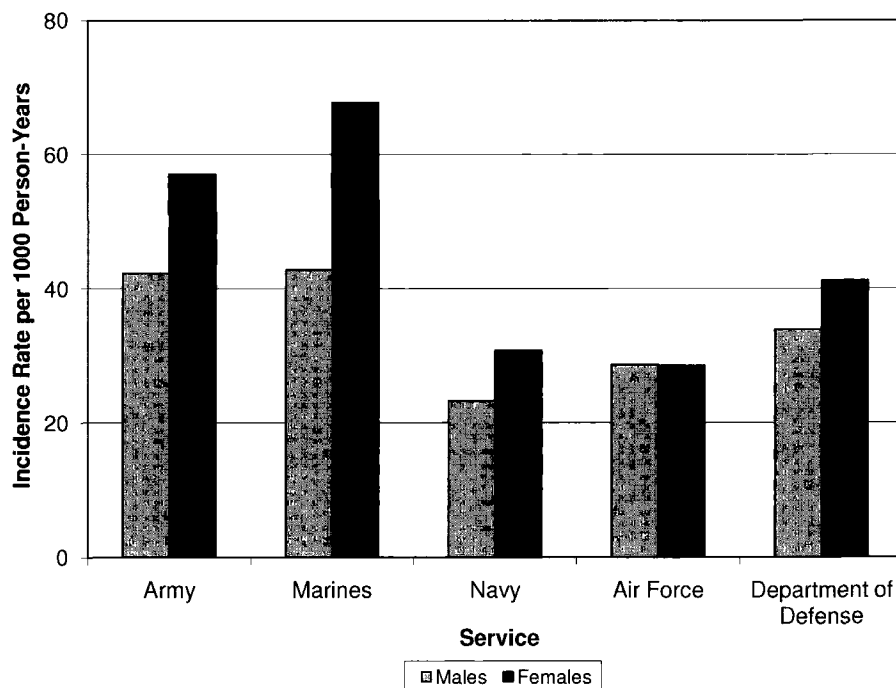


Figure 2. Incidence of ankle sprains in the US Armed Services by service and sex.

discrepancies between males and females were among service members who were less than 20 years of age, followed by those who were 40 years or older. Females in the Marine Corps were nearly twice as likely as males to experience ankle sprains if they were less than 20 years of age. Females in the Army and Navy were 68% and 67% more likely, respectively, to be injured than males in the youngest age group.

Injury patterns in Air Force personnel were notably different than those in the other 3 branches of military service. As indicated above, when all age groups were examined collectively, males and females on active duty in the Air Force experienced ankle sprain injuries at an equal rate. As was the case for the other branches of service, IRs were highest for both males and females in the under 20-year age group, and rates declined with age. Active-duty females in the Air Force who were younger than 20 years of age and those 40 years or older experienced higher rates for ankle sprains than did males in the same age groups (Table 1). In contrast to the findings for the other branches of service, females in the Air Force experienced lower rates of ankle sprain injuries in the 20 to 24-year, 25 to 29-year, and 30 to 34-year age groups than did males in the same age groups. Males and females aged 35 to 39 years experienced equal rates of ankle sprain injuries. Differences in the incidence of ankle sprain injuries by sex were noted among branches of military service (Table 2). Among active-duty males, differences in IRs were seen among branches of military service in all age groups (Table 3). Similar to the findings for males, differences in IRs were noted among branches of military service among females in each age group, with few exceptions (Table 4).

DISCUSSION

Ankle sprains are common injuries within military populations.^{1-3,12-14} According to several studies,¹⁻³ the

majority of ankle sprains documented within military personnel result from participation in organized and recreational sports, exercise, and physical training. Ankle sprains are not an isolated problem affecting US service members, as authors have documented a high rate of sport-related, exercise-related, and physical training-related ankle sprains in British Army^{3,13} and New Zealand Defense Force² populations. Lauder et al¹ found that ankle injuries, and ankle sprains specifically, were second only to knee injuries among hospital admissions for sport-related and physical training-related injuries between 1989 and 1994 in the US Army. Jones et al¹⁵ noted that ankle sprains were the most prevalent injury related to physical training among men in the US Army, accounting for 35% of all lower extremity injuries, and the third most prevalent injury (of all injuries) during Basic Combat Training (6.3%). Similarly, Almeida et al¹⁶ studied musculoskeletal injury rates among men and women during US Marine Corps recruit training and discovered that ankle sprain was the second most commonly reported injury, regardless of sex. Despite the effect of ankle sprains on physical and operational readiness within military populations, the incidence of ankle sprains among US service members has not been examined thoroughly, and most investigators have focused on injuries resulting in hospitalizations¹ or those related to Basic Combat Training.^{15,16} Furthermore, no authors have examined the incidence of ankle sprain injuries across all 4 branches of US military service.

We studied the IR for ankle sprain injuries for all active-duty US service members over a 9-year period from 1998 through 2006. Overall, the IR for ankle sprain injuries among all active-duty US service members was 34.95 per 1000 person-years at risk to injury. Davidson et al² reported an overall incidence rate of 160 lower extremity injuries per 1000 person-years at risk among members of the New Zealand Defense Force. Although ankle sprains were the most commonly documented injury in this cohort,

Table 1. Ankle Sprain Incidence Rates, Incidence Rate Ratios, and 95% Confidence Intervals by Age, Sex, and Service Branch

Age Group	Army	Marines	Navy	Air Force	All Services
<20 y					
Male incidence rate	77.51	82.43	38.93	49.41	64.57
Female incidence rate	129.97	157.19	64.90	62.44	96.35
Incidence rate ratio ^a	1.68	1.91	1.67	1.26	1.49
95% Confidence interval	1.64, 1.72	1.83, 1.99	1.60, 1.74	1.21, 1.32	1.47, 1.52
P value	<.001	<.001	<.001	<.001	<.001
20–24 y					
Male incidence rate	52.64	42.82	26.08	40.95	41.58
Female incidence rate	62.88	56.77	31.06	32.72	44.11
Incidence rate ratio ^a	1.19	1.33	1.19	0.80	1.06
95% Confidence interval	1.17, 1.22	1.27, 1.38	1.16, 1.23	0.78, 0.82	1.05, 1.08
P value	<.001	<.001	<.001	<.001	<.001
25–29 y					
Male incidence rate	41.41	35.63	25.47	29.87	33.62
Female incidence rate	49.61	42.52	26.52	24.87	34.95
Incidence rate ratio	1.20	1.19	1.04	0.83	1.04
95% Confidence interval	1.17, 1.23	1.10, 1.29	1.00, 1.09	0.80, 0.87	1.02, 1.06
P value	<.001	<.001	<.064	<.001	<.001
30–34 y					
Male incidence rate	33.22	24.96	19.78	22.36	25.81
Female incidence rate	41.77	36.07	23.50	19.34	29.45
Incidence rate ratio	1.26	1.44	1.19	0.86	1.14
95% Confidence interval	1.21, 1.30	1.27, 1.64	1.12, 1.28	0.82, 0.91	1.11, 1.17
P value	<.001	<.001	<.001	<.001	<.001
35–39 y					
Male incidence rate	25.48	21.53	17.17	19.35	20.85
Female incidence rate	29.49	30.24	20.61	18.63	23.31
Incidence rate ratio	1.16	1.40	1.20	0.96	1.12
95% Confidence interval	1.10, 1.21	1.20, 1.65	1.12, 1.28	0.91, 1.02	1.08, 1.15
P value	<.001	<.001	<.001	<.204	<.001
≥40 y					
Male incidence rate	19.27	17.17	13.94	15.91	16.51
Female incidence rate	24.43	27.45	20.55	18.12	21.13
Incidence rate ratio	1.27	1.60	1.47	1.14	1.28
95% Confidence interval	1.20, 1.35	1.28, 2.00	1.37, 1.59	1.07, 1.22	1.23, 1.33
P value	<.001	<.001	<.001	<.001	<.001
All age groups combined					
Male incidence rate	42.34	42.83	23.25	28.65	33.89
Female incidence rate	56.99	67.76	30.76	28.46	41.17
Incidence rate ratio	1.35	1.58	1.32	0.99	1.21
95% Confidence interval	1.33, 1.36	1.54, 1.62	1.30, 1.35	0.98, 1.01	1.21, 1.23
P value	<.001	<.001	<.001	<.433	<.001

^a All incidence rate ratio comparisons were calculated with females as the referent group (eg, females in the Army were at 1.68 times [68%] greater risk than males in the under 20-year age group).

Table 2. Incidence Rate Ratios and 95% Confidence Intervals Between Branches of Military Service by Sex

	Males			Females		
	Incidence Rate Ratios	95% Confidence Interval	P Value	Incidence Rate Ratios	95% Confidence Interval	P Value
Marines–Army ^a	1.01	1.00, 1.02	<.017	1.19	1.16, 1.22	<.001
Marines–Navy	1.84	1.82, 1.86	<.001	2.20	2.14, 2.27	<.001
Marines–Air Force	1.50	1.48, 1.51	<.001	2.38	2.31, 2.45	<.001
Army–Navy	1.82	1.81, 1.84	<.001	1.85	1.82, 1.89	<.001
Army–Air Force	1.48	1.47, 1.49	<.001	2.00	1.97, 2.04	<.001
Navy–Air Force	0.81	0.80, 0.82	<.001	1.08	1.06, 1.11	<.001

^a All incidence rate ratio comparisons are relative to the first group listed (eg, female Marines were at 1.19 times [19%] greater risk than females in the Army).

Table 3. Male Incidence Rate Ratios and 95% Confidence Intervals Between Military Service Branches by Age

	Marines–Army ^a	Marines–Navy	Marines–Air Force	Army–Navy	Army–Air Force	Navy–Air Force
Age group						
<20 y						
Incidence rate ratio	1.06	2.12	1.67	1.99	1.57	0.79
95% Confidence interval	1.04, 1.09	2.06, 2.17	1.63, 1.72	1.94, 2.04	1.53, 1.61	0.76, 0.81
P value	<.001	<.001	<.001	<.001	<.001	<.001
20–24 y						
Incidence rate ratio	0.81	1.64	1.05	2.02	1.29	0.64
95% Confidence interval	0.80, 0.83	1.61, 1.67	1.03, 1.06	1.99, 2.05	1.27, 1.30	0.63, 0.65
P value	<.001	<.001	<.001	<.001	<.001	<.001
25–29 y						
Incidence rate ratio	0.86	1.40	1.19	1.63	1.39	0.85
95% Confidence interval	0.84, 0.88	1.36, 1.44	1.16, 1.23	1.59, 1.66	1.36, 1.41	0.83, 0.87
P value	<.001	<.001	<.001	<.001	<.001	<.001
30–34 y						
Incidence rate ratio	0.75	1.26	1.12	1.68	1.47	0.88
95% Confidence interval	0.72, 0.78	1.21, 1.31	1.07, 1.16	1.64, 1.72	1.44, 1.51	0.86, 0.91
P value	<.001	<.001	<.001	<.001	<.001	<.001
35–39 y						
Incidence rate ratio	0.84	1.45	1.11	1.48	1.32	0.89
95% Confidence interval	0.81, 0.88	1.40, 1.51	1.06, 1.17	1.44, 1.53	1.28, 1.35	0.86, 0.92
P value	<.001	<.001	<.001	<.001	<.001	<.001
≥40 y						
Incidence rate ratio	0.89	1.23	1.08	1.38	1.21	0.88
95% Confidence interval	0.84, 0.95	1.16, 1.31	1.01, 1.15	1.33, 1.44	1.17, 1.26	0.84, 0.91
P value	<.001	<.001	<.017	<.001	<.001	<.001

^a All incidence rate ratio comparisons are relative to the first group listed (eg, Marines are at 1.06 times [6%] greater risk than Army members in the <20-year age group but 0.81 times [19%] less likely to be injured in the 20 to 24-year age group).

IRs for ankle sprains specifically were not provided, making comparisons with our findings difficult. Waterman et al¹⁷ described the incidence and risk factors for ankle sprain injuries among cadets at the US Military Academy. The overall rate of ankle sprain injuries among cadets at

the Military Academy was 58.4 per 1000 person-years, which is similar to the rates observed within the under 20-year and 20 to 24-year age groups in our present study.

We observed higher IRs for ankle sprain injuries than have previously been reported in the literature for civilian

Table 4. Female Incidence Rate Ratios and 95% Confidence Intervals Between Military Service Branches by Age

	Marines–Army ^a	Marines–Navy	Marines–Air Force	Army–Navy	Army–Air Force	Navy–Air Force
Age group						
<20 y						
Incidence rate ratio	1.21	2.42	2.52	2.00	2.08	1.04
95% Confidence interval	1.16, 1.27	2.30, 2.55	2.37, 2.66	1.92, 2.09	2.00, 2.17	0.99, 1.09
P value	<.001	<.001	<.001	<.001	<.001	<.133
20–24 y						
Incidence rate ratio	0.90	1.83	1.74	2.02	1.92	0.95
95% Confidence interval	0.87, 0.94	1.74, 1.92	1.66, 1.82	1.96, 2.09	1.87, 1.98	0.92, 0.98
P value	<.001	<.001	<.001	<.001	<.001	<.004
25–29 y						
Incidence rate ratio	0.86	1.60	1.71	1.87	1.99	1.07
95% Confidence interval	0.79, 0.93	1.47, 1.75	1.57, 1.86	1.79, 1.96	1.91, 2.08	1.01, 1.12
P value	<.001	<.001	<.001	<.001	<.001	<.016
30–34 y						
Incidence rate ratio	0.86	1.54	1.86	1.78	2.16	1.21
95% Confidence interval	0.76, 0.98	1.34, 1.75	1.64, 2.13	1.67, 1.89	2.04, 2.29	1.13, 1.31
P value	<.021	<.001	<.001	<.001	<.001	<.001
35–39 y						
Incidence rate ratio	1.03	1.47	1.62	1.43	1.58	1.11
95% Confidence interval	0.87, 1.21	1.24, 1.74	1.38, 1.91	1.33, 1.55	1.48, 1.70	1.02, 1.20
P value	<.761	<.001	<.001	<.001	<.001	<.017
≥40 y						
Incidence rate ratio	1.12	1.34	1.51	1.19	1.35	1.13
95% Confidence interval	0.90, 1.40	1.07, 1.67	1.21, 1.89	1.09, 1.30	1.24, 1.46	1.03, 1.24
P value	<.300	<.012	<.001	<.001	<.001	<.008

^a All incidence rate ratio comparisons are relative to the first group listed (eg, Marines are at 1.21 times [21%] greater risk than Army members in the <20-year age group but 0.90 times [10%] less likely to be injured in the 20 to 24-year age group).

populations.^{18,19} In a population-based epidemiologic study¹⁸ conducted in the West Midlands of England, the IR for ankle sprain injuries was 5.27 to 6.09 per 1000 person-years at risk. Similarly, in research¹⁹ conducted at a Denmark hospital, the incidence was 7.00 injuries per 1000 person-years at risk based on patients seen in the casualty ward during a 1-year period. The IR for ankle sprains was nearly 5 times greater in our study than in civilian studies previously reported in the literature.

Several factors may have contributed to the differences in the observed IRs between our study and the 2 previously published population-based epidemiologic investigations among civilians. The population for the current study only included active-duty US service members, a population constituting a large, physically active cohort that engages in physical training and recreational sports on a regular basis.¹ In comparison, previous authors have examined injuries in the general population in European Union countries. Differences in the US Military Healthcare System and European health care systems may also be factors. Most likely, however, differences in observed IRs between the current study and previously published results can be attributed to the manner in which the data were collected. Previous investigators have primarily used hospitalization and emergency department visits to document injuries and calculate IR estimates, thereby excluding injuries seen in ambulatory settings. We examined ambulatory visits for ankle sprain injuries, including both clinic and emergency department visits within a closed health care system with free and open access to treatment.

Overall, females in the present study experienced ankle sprain injuries approximately 21% more often than males when all service members were examined collectively, regardless of age or branch of military service. Several authors^{4,20–24} have demonstrated that females are at greater overall risk for injury than males during Basic Combat Training. Risk ratios between males and females during Basic Combat Training have ranged between 1.6 and 2.5, indicating that females are at 1.6 to 2.5 times greater risk of injury than males.^{4,20–24} A consistent finding across studies is that the ankle is one of the most common sites of injury for females during Basic Combat Training.^{4,16} This may explain why the greatest discrepancy in the IR for ankle sprains between males and females was noted in the youngest age group in our study. The youngest age group accounts for most of the Basic Combat Training injuries documented in DMSS. Strowbridge¹³ reported that females in the British Army were nearly twice as likely as males to experience sprains to the ankle and foot. Although an increased risk for injury among females during Basic Combat Training in general and for ankle sprains specifically may explain the largest difference in the incidence of ankle sprains between males and females in our study, it does not explain differences in all other age groups among US service members. Despite statistical significance, sex differences for the incidence of ankle sprains only appear to be clinically significant (ie, more than 15% different) for the youngest (less than 20 years) and oldest (40 years or older) age groups when all service members were examined collectively; however, clinically significant sex differences were noted for most age groups when each branch of service was examined independently.

Sex-specific IRs for ankle sprain varied by age. In general, the incidence of ankle sprain was higher among younger service members and decreased with age. Among all active-duty US service members, younger females were seen for ankle sprain injuries 49% more frequently than were males of the same age. These differences appear to narrow with age but increase once again as service members near the age of 40 years. Active-duty females 40 years of age or older were seen for ankle sprains at a rate that was 28% higher than that for males in the same age group. This pattern was consistent across each branch of military service when examined individually, with females 40 years or older experiencing ankle sprain injuries between 14% and 60% more frequently than males (Table 1). Similar patterns related to the incidence of ankle sprain by sex and age have previously been described in the literature.¹⁸

Important sex differences associated with ankle sprains have been noted in other studies.^{18,25–27} In one population-based study,¹⁸ females between the ages of 10 and 14 years were reported to experience the highest rate of ankle sprains within the cohort examined. The IRs among cadets at the US Military Academy indicate that female athletes experienced ankle sprain injuries nearly twice as often as their male counterparts.¹⁷ Within other athletic populations, females have been reported to be at greater risk for ankle sprain injuries than males. Females were between 1.25 and 4.11 times as likely to experience ankle sprain injuries than were males in the same sport.^{25–27} The relative risk for ankle injuries in general among adolescent soccer players was 38% greater in females than in males, and the relative risk for sprains or strains to the ankle specifically was 36% greater.²⁷ Other groups^{25,26} have shown differences in the incidence of ankle sprains between male and female basketball players, with females being at greater risk for injury. Conversely, some authors^{28,29} have reported no difference in the incidence of ankle sprain injuries between male and female athletes. Despite these reports, the underlying factors that place females at greater risk for ankle sprain injuries in certain settings (when compared with males) remain unclear.

The IRs and injury patterns for ankle sprains by sex and age varied within and between branches of military service. Although the overall IR and injury patterns were similar for males and females within the Marine Corps, Army, and Navy, the pattern within the Air Force was notably distinct. Females experienced higher rates of ankle sprain injuries than males in all 18 age-group categories across the Marine Corps, Army, and Navy except one, and these differences appear to be of clinical importance (>15% difference). Males and females in the 25 to 29-year age group serving in the Navy experienced equal rates of injury. In the Air Force, females experienced greater rates of ankle sprain injuries than males in the youngest (<20 years) and oldest (≥40 years) age groups studied, but males experienced ankle sprains more often between the ages of 20 and 34 years. Males and females between the ages of 35 and 39 years on active duty in the Air Force experienced equal rates of ankle sprain injuries. Although the Air Force changed its fitness standards on January 1, 2004, the overall rate of ankle sprain injuries in this population did not seem to be affected. Distinct occupational risk factors within the Air Force may place males on active duty at

greater risk of injury than females. Conversely, occupational factors may serve to protect females from the risk of sustaining an ankle sprain. Further research is indicated to identify and examine the role of potential occupational risk and protective factors that may contribute to the distinct injury patterns observed among active-duty Air Force personnel.

Clinically significant differences were most noteworthy between those serving in the Army and Marine Corps compared with those serving in the Navy and Air Force, as represented by a $\geq 15\%$ difference in the IRs. Occupational risk factors for ankle sprain injuries for both males and females appear to depend on the specific branch of military service. These differences likely result from the distinct operational mission of each branch, which requires a different level of physical fitness and physical training. These differences may also be the result of different cultural values related to physical activity and participation in competitive sporting activities among the 4 branches of military service. Behavioral factors, such as risk propensity, may also explain the differences in the rate of ankle sprain injuries observed among services in the present study; they may also explain the increased rates of injury in the younger age groups.³⁰⁻³² Direct combat and close-support occupational groups were twice as likely to engage in risk-taking behaviors than were other occupational groups,³³ and the majority of US service members in the Army and Marine Corp fall into these occupational categories.

The burden of ankle sprain injuries within military populations is significant.¹ Among service members, ankle sprains frequently result in time loss and persistent disability⁶ and are second only to low back pain in relation to the overall percentage of rehabilitation workload.³ Strowbridge and Burgess³ reported that ankle sprain injuries among British Army personnel required an average of 40 days of rehabilitation. Gerber et al⁶ noted persistent disability associated with ankle sprains during a prospective investigation within a cohort of cadets at the US Military Academy at West Point. Even though 95% of patients with ankle sprains returned to sports and physical training activities within 6 weeks of injury, functional deficits and residual symptoms were noted at the 6-week and 6-month follow-up evaluations. At 6 weeks after injury, 55% of patients reported loss of function and intermittent pain, and 23% demonstrated a 20% or greater decrement on functional testing. At 6 months after injury, 40% still reported residual symptoms, and 2.5% demonstrated 20% or greater deficits on functional tests. Several groups^{14,16,17} have documented that military personnel with a history of ankle sprain injuries are more likely to sustain subsequent ankle sprain injuries. Knapik et al¹⁴ reported that officers at the US Army War College were more than 6 times more likely to sustain an ankle sprain if they had reported an ankle sprain within the 5-year period before attending the school.

For our study, a notable limitation of the injury data contained within DMSS is that they are not linked to data that could be used to assess the effect of injuries. No data for time loss from injury, rehabilitation workload, or injury-related disability and subsequent discharge due to injury are available in DMSS. It should be a Department of Defense priority to coordinate medical profile and disability information into subsequent versions of the Armed

Forces Health Longitudinal Technology Application and, subsequently, the Standard Ambulatory Data Record for documenting all ambulatory visits in DMSS.

Some additional limitations of the present study are evident. The overall quality of medical surveillance data depends on the completeness, validity, consistency, timeliness, and accuracy of the data overall.⁸ Despite the comprehensive nature of the injury data collected and stored in the DMSS, common data-quality issues associated with large administrative health care databases cannot be overlooked. Errors such as miscoding data at the health care provider or coding department level or failure to complete data records may affect overall data quality within the DMSS. This is a common concern when conducting epidemiologic research using large-scale administrative health care data systems. These factors may result in either overestimation or underestimation of the true incidence of ankle sprain injuries within this population. Another limitation is that by including only the first occurrence of injury in our data, we may have missed some instances of recurrent or contralateral injury over the 9-year study period, which may have also suppressed the actual incidence of injury in the current study.

Finally, during the study period, more than 90% of all ankle sprains were coded with either ICD-9 codes 845.00 (unspecified ankle sprain) or 845.09 (other ankle sprain). The fact that more than 90% of all injuries documented during the study period were coded as "unspecified" or "other" ankle sprains is troubling and may reflect either inadequate coding mechanisms within the ICD-9 coding system or diagnoses determined by multiple providers with various levels of skill and specialty training. Furthermore, the lack of a specific ICD-9 code for sprains of the anterior talofibular ligament, which is injured in nearly all lateral ankle sprains,⁵ makes it difficult to identify the specific structures injured. Better codes that differentiate among the lateral ligamentous structures of the ankle and include the most commonly injured ligament about the ankle (anterior talofibular ligament) might improve data quality and interpretation in future studies.

Despite the data limitations noted above, the ambulatory data contained within the DMSS provide many advantages over data from similar civilian systems. First of all, data are collected for all visits for the population of interest (eg, US service members on active duty) using standardized inpatient and ambulatory data records. All ambulatory encounters that meet the data-quality requirements for DMSS are included in the present study.⁸ The US Armed Forces Health Surveillance Center makes a concerted effort to ensure a standardized and consistent approach to data processing and validation.⁸ Furthermore, accurate demographic and person-time at risk to injury data are included in the DMSS through the Defense Manpower Data Center. The person-time at risk information provides excellent denominator data for calculating IRs for the entire active-duty military population.³⁴ Another strength of this investigation is the large and physically active population that was studied. Although this population may not be comparable with the general population of the United States, it may represent the segment of the population that is actively engaged in recreational sports and exercise. This segment of the population is growing as recreational sports and exercise

continue to become more popular and widespread in American culture. This segment of the population is also important because of the increasing burden that recreational sports and exercise-related injuries place on the health care system, according to the Centers for Disease Control and Prevention.³⁵ A final strength of this study is that we examined ankle sprains treated in ambulatory clinics within a large, closed health care system. Prior authors investigating the incidence of ankle sprains have relied on documenting injuries treated in hospitals and emergency departments and may have missed a large proportion of injuries treated in other practice settings.

CONCLUSIONS

This study is one of the first large-scale, population-based epidemiologic studies to examine the incidence of ankle sprain injuries and the first to examine ambulatory data within a military population. Overall, the IR for ankle sprain injuries in the current study was more than 5 times greater than that previously reported in civilian populations. Important distinctions related to the incidence of ankle sprains were noted by sex, age, and service. Future researchers should focus on further identifying the modifiable and nonmodifiable risk factors for ankle sprain injuries in this population. The results of this research should then be used to develop injury prevention initiatives. Certified athletic trainers may play a critical role in this area of injury care, injury prevention, and program evaluation.

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